DUST IN INDUSTRY

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THERE are only a very few distinct diseases or diseased conditions which are strictly speaking occupational in origin, such as the specific metallic poisonings, gas and fume poisoning, "Caisson disease" caused by working in compressed air, an anthrax infection from working with infected hides or wool. Other diseases, just as serious and just as truly due to improper working conditions, may be directly traceable to occupational hazards, however, though they may also be caused by or aggravated by other conditions outside of daily work. In these latter instances it is often hard to tell just how much of the trouble is due to faulty working conditions and how much to faulty personal hygiene of the worker at home or elsewhere. As working conditions and manufacturing processes differ so widely in different countries and even in different localities in the same factory, observations made at one time and place do not necessarily hold good as the basis of generalizations. To rightly judge of any industry and of its effect on health studies must not only be made in one place or one factory but in many factories in different localities.

A number of such investigations have been conducted in specially dangerous industries and have resulted in very greatly improved conditions, and in several of our very large cities special clinics have been instituted to treat occupational diseases and to make further studies of working conditions.

Some employers take every precaution they know of to lessen danger to their workmen, not only for the sake of the workers, but because employers are coming more and more to realize that a healthy, vigorous worker is even more valuable than a piece of machinery kept in good repair and well oiled. On the other hand, there are a great number of employers whose only aim is to secure a greater production in less time and at less cost, and who fail to appreciate the drawback to such an aim that unhealthy workmen, poor light, clutter and dirt really are. Bearing these facts in mind, one can see the value of intensive studies of health-hazardous industries in various localities, so that we may learn if possible the part

played in disease production by the special hazards and how far these hazards may be lessened or removed, or the workers protected from their bad effects. Among non-specific disease-producers found in industry none is of much greater importance and more generally prevalent than dust. Many industries necessarily are associated with dust in large quantities and often of very irritating nature, though too often much more dust is produced than necessary and that which is produced is scattered over a far wider area than need be.

Dusts produced in industry may be of various kinds and their harmful action on the system depends on the nature of the dust as well as on the amount. These dusts have been classified in several ways. First, as to whether they are mineral, metallic, vegetable or animal in origin, or mixed, but this grouping gives no definite idea as to their action. From the health standpoint a better classification is into irritating, poisonous and infectious. Dust in the air we breathe is inhaled and if insoluble may act more or less as an irritant to tissues with which it comes in contact, depending on the shape and hardness of the particles, hard, sharply pointed or angular particles like flint or steel being much more harmful than smooth clay or soft vegetable or animal fiber dust. Such insoluble dust, particularly animal fiber or hair dust, may carry into the system with it the germs of infectious disease, and many fatal cases of anthrax have been caused by inhaling the dust liberated in the sorting of infected wool or hides. Tubercle bacilli are often thus introduced on dried or drying particles of sputum carelessly expectorated by infected workers.

Soluble dusts are dissolved in the mucus covering the linings of the air passages and may act locally as chemical irritants, causing local catarrhal inflammations, which in turn lower the resistance of the tissues and facilitate the lodgment and growth of pus-producing bacteria, or the poison may be absorbed into the system and cause general poisoning, the most frequent examples of the latter being the numerous cases of lead poisoning occurring among painters, sand paperers and makers and users of white lead, red lead and litharge.

It is remarkable how much dust one can become accustomed to with apparently very little harm being done. This is partly due to the action of the excellent defenses nature has provided. Large heavy particles very soon fall to the floor and if the place of generation of dust is below the level of the nose or mouth of the worker these particles may never reach the respiratory passages unless they are thrown upward with force. Of those

particles of irritating insoluble dusts that reach the nasal openings and are inhaled fibers of any length are apt to be caught and retained by the hairs in the nostrils, while a certain percentage of the larger and medium-sized masses and even some of the smaller ones are deposited on the moist membranes of the nasal passages and eventually swallowed with the mucus from the back of the throat or sneezed or blown out of the nostrils. Only the finer particles penetrate to the trachea and bronchi, and there any that lodge on the walls of the larger air passages are swept upward by the current of mucus kept in motion by the countless little whip-like processes of the cells lining these tubes. So finally only the smallest particles, one authority says those under $\frac{1}{100}$ millimeter in size, reach the lungs themselves. Lehmann, working with white lead dusts, found that from 35 to 43 per cent. by weight of that entering the nostrils reached the lungs, the rest either being finally swallowed or breathed, blown or sneezed out of the nares. Insoluble dusts that do reach the finer bronchioles or air cells are taken up by wandering cells or phagocytes and carried into the tissues, or by means of their sharp edges or points work their own way in and there give rise to local inflammation, followed by an increase of fibrous connective tissue, especially marked around the small blood vessels and air passages. This firm non-elastic fibrous tissue replaces the normal more elastic tissue and crowds and contracts the small air passages. The former prevents the normal expansion and contraction of the lungs with respiration and the latter causes dilation of the terminal air cells due to increased resistance to expiration and hinders the normal flow of blood in the lungs, so lessening the amount of oxygen taken up by the blood and the amount of carbon dioxide given off. This slows up the normal tissue metabolism and lowers the general body tone, lessening resistance to disease, especially to infections of the respiratory tract. Such fibrosed lungs yield more readily to attacks of infective bronchitis and pneumonia, and many claim also that they make excellent soil for the development of tuberculosis, though when tuberculosis does develop it is more apt to be a slow chronic process owing to this very immobility of the lungs preventing the rapid spread of infection and giving nature more chance to build a protective wall around the diseased area. Some of the dust particles which the wandering scavenger cells carry into the tissues reach the lymph channels and are arrested in the lymph glands at the root of the lungs, where they remain out of harm's way and do no further damage unless infected. Such glands after death from

other causes are found swollen and loaded with gritty particles.

This brief sketch of the fate of inhaled dust shows the importance of dust prevention as a health measure in industry and the value of accurate data as to the volume of dust generated in different processes and the relative proportions of different-sized particles in this dust, as well as the shape and hardness of those minute particles which reach the lungs themselves. Such data as to the amount of dust inhaled have heretofore been very scarce and as a rule based on the amount of dust in comparatively small samples of air, at most a few cubic feet, and often small fractions of a cubic inch, and as air currents in rooms are constantly changing in force and direction, especially if there is much motion of persons or machinery, and as dust production in manufacturing processes varies from moment to moment, such small samples give no reliable picture of actual conditions. The investigators of the New York State Ventilation Commission two years ago developed a new testing apparatus by means of which much larger samples of air can be examined, such sampling extending over appreciable periods of time, so that much more nearly average conditions can be obtained and more reliable conclusions and estimates can be made. This apparatus, the Palmer dust-collecting machine, is essentially an electrically driven centrifugal fan which aspirates a continuous current of air through a fountain of water in a specially designed bulb. All the particles of any but ultramicroscopic size which are floating in the air are retained in the water, a gasoline manometer enabling one to measure the rate of flow of air through the machine. After a test the water is drawn off into a clean bottle and diluted up to a given volume. Knowing the amount of air sampled and the volume of water we know the volume of air that a given fractional amount of the water will represent. This water can then be evaporated and the residue weighed, to determine the weight of dust. The dried dust can be burned and again weighed to determine the proportion of organic and mineral matter present. Chemical tests can be made to determine the amount of any poisonous substances present and finally the dust particles can be examined under a microscope to determine their shape and size and number per unit of air, usually per cubic foot, as well as the relative number of particles of different sizes. For the last-mentioned purposes the commission recommends grouping particles in four or five groups, the smallest being about ten times the diameter of the average bacteria, and the largest about 400 times larger. Those under 0.001 millimeter

can not well be counted, and in the work to be referred to here have been disregarded, as they are considered too small to do any serious harm. With this apparatus, samples of from 25 to 200 cubic feet or more of air can be tested, the amount depending on the dustiness of the air. As the optimum rate of sampling is five cubic feet per minute, it will be seen that tests lasting from five to forty minutes give time for normal variations in air currents and dust produced to occur. In this way, the amount of dust per hundred cubic feet of air can be estimated in the shorter tests and actually weighed in tests of 100 to 200 cubic feet. As the average man inhales 30 cubic inches of air at each inspiration and breathes 17 to 18 times per minute, it is estimated that he would inhale about 18 cubic feet of air per hour or 144 cubic feet in an 8-hour working day. With these figures as a basis, it is easy to estimate the weight of dust and its percentage of organic and inorganic matter which a worker would inhale in his working day, of whatever length it may be, in his particular industrial occupation. Assuming that Lehmann's estimate of 42 per cent. of inhaled dust particles actually reaching the lungs and remaining there might be too high for some dusts, it is calculated that at least one third of inhaled dust would actually remain in the lungs.

Last winter the University of Pennsylvania Hospital established a clinic for occupational diseases in cooperation with the Pennsylvania State Department of Labor and Industry. In addition to the routine work of treating patients referred from industrial plants and to making special investigations of the working conditions of these patients, the clinic is engaged in a systematic study of dust hazards and distinctively dusty industries.

The study referred to includes surveys of the industries with determination of the relative humidity in the work rooms, as the amount of moisture in the air influences greatly the amount of dust remaining suspended in the air. Determinations were made, by the use of the Palmer apparatus described above, of the actual average weight of dust per cubic foot in the air of the work rooms, with the estimation of the total amount of dust a worker would inhale in a day's work. Estimations were made of the number of dust particles per cubic foot of air and these were grouped into four different sizes, with the determination of the percentage of each size in the total count, and the determination of the character of the dust, including shape of particles, percentage of organic and mineral matter and amount of any poisonous substances, if present.

Also physical examinations were made and medical histories taken of many employees, preferably of men who had been working a number of years in dusty trades. Finally the rœntgenologic department of the University Hospital made rœntgenographic examinations and radiograms of the chests of these workers, as that is where the effects of long-continued work in dusty atmosphere are chiefly seen.

The value of such work to the industrial physician, the worker and the industry itself can be readily seen. It is thought that a few of the results obtained and the conditions observed might be of interest to the general reader. For purposes of comparison and as a basis of standardization, air was examined in a suburban house and in a laboratory of the university to obtain an indoor standard, and outdoor samples were collected at the same places. The following table gives the number of particles per cubic foot of air, the weight of dust inhaled per working day, with the minimum amount retained in the lungs per day and per year of 300 working days in each industry examined. Each report is an average of tests taken in that industry in different rooms and departments and often in different factories. Sixty-five tests in all were made in nine industries and five tests for comparison which were calculated for twenty-four hour periods. The working days in the industries ranged from eight to twelve hours in length, the longest day being in the dustiest industry. Portland cement making was by far the dustiest trade investigated, and here the actual bulk of dust inhaled is amazing, but the reason for this will be seen when it is stated that from one room in one plant calculations showed that at least half a ton of cement dust and probably much more escaped into the surrounding atmosphere in a day. In a similar room at another plant, there were only about one sixth as many particles in the air, and of these a greater number were of the larger sizes, due to the exhaust ventilation stacks over conveyors which carried off many of the smaller, more dangerous particles. Men were found who had been working over twenty years in cement plants, and the table will show that they must have had from 2 to 4 pounds of cement dust lodged in their chests. Next to cement in the amount of dust created came plush and carpet making and here considerable variations were found in different rooms. The dustiest places were the wool breaker room where dirty raw wool was handled which might readily be contaminated with dangerous disease germs, and another room where old woolen rags of all descriptions were shredded up to be made over into carpet.

RESULTS OF DUST TESTS IN INDUSTRY

Industry	No. of Tests	Dust Particles per Cubic Ft.	Wt. of Dust Inhaled per Diem (in Grams)	Wt. of Dust Inhaled per 300-Day Yr. in Grams	Wt. of Dust Retained per 300-Day Yr. in Ounces	1 Lb. of Dust Retained in	Hours in Day's Work
Portland cement mfgr.	11 (2 factories)	6,790,900	0.4559 grams	146.77 grams	1.466 ounces	10.9 yrs.	12
Plush, blanket and carpet weaving	13	148,950	0.0906 "	27.18 "	0.291 "	56 "	10
Steel grinding	3 (2 factories)	578,100	0.0861 "	25.83 "	0.277 "	57 "	9.8–10
Flint grinding	3 (2 factories)	844,040	0.0663 "	19.89 "	0.213 "		8
Asbestos weaving	6 (2 factories)	494,130	0.0573 "	17.19 "	0.185 "		8–10.25
Felt hat making	3	126,020	0.0242 "	7.26 "	0.077 "		8
Pottery mfgr.	5 (3 factories)	182,720	0.0187 "	5.61 "	0.06 "		8
Cigar mfgr.	19 (6 factories)	102,600	0.0147 "	4.41 "	0.047 "		9.75
Silk weaving	2	87,000	0.0081 "	2.43 "	0.026 "		10
Indoor air average	3 (2 locations)	99,600	0.0492 in 24 hrs.	17.96 in 365 day yr.	0.173 in 365 day yr.		
Outdoor air average	2 (2 locations)	34,000	0.0299 in 8 hrs.	10.92 gm. in 365 day yr.	0.105 gm. in 365 day yr.		
Total	70						
Dustiest cement room		13,560,000	1.0644	319.32 gm. in 365 day yr.	3.419	4.7 yrs.	12
Dustiest wool room		430,400	0.7027	210.81 " " "	3.26	7.08 "	10
Dustiest steel grinding room		1,066,200	0.1599	47.97 " " "	0.514	31 + "	9.8
Dustiest asbestos working room		356,800	0.1161	34.83 " " "	0.373	45 + "	10.25

Here too there was danger of infection as well as mechanical injury from dust. However, woolen dust itself is among the least irritating of dusts, far less so than the hard mineral dusts.

Steel and asbestos dusts are both decidedly irritating, the former being distinctively dangerous, owing to its sharp irregular form. In the dustiest streel-grinding room ball bearings were being dry ground between emery wheels and no effort was made to keep the fine particles from flying off into the air. The asbestos dusts would have averaged much higher except for the presence of very efficient exhaust ventilation hoods over the carding machines in one factory. As will be seen at the bottom of the accompanying table, one asbestos working room was even worse than the ball-grinding room. Flint dust, though ranking fourth in the table, is probably the most dangerous of all except possibly steel, and flint has a reputation for shortening the lives of workers and inducing tuberculosis. One flint mill has an exhaust system, but, as often is the case, it was not working. Pottery manufacturing has a bad name, but conditions were not found to be very bad, as will be seen. Formerly much lead was used in pottery glaze and is yet for some wares, but little was used in the factory visited, the employees being well protected when it was used, and a test of the dust showed only a small per cent. of lead present.

The danger in felt hat making is not so much from the fur dust itself as from the mercury dust, rising from the carrotted fur. The fur is "carrotted" or brushed with acid nitrate of mercury solution to prepare it for the felting process. Cigar manufacturing has a bad name for dust production, but, as seen in Philadelphia, this is undeserved and nicotine tests on the dust showed little or no danger of poisoning of the workers.

The silk factory was the cleanest place visited, and here there was less dust than found anywhere except in outdoor country air. This is partly due to the high degree of relative humidity maintained to make the silk fibers more manageable.

In many of the places where samples were taken relative humidity was tested, and in general it was seen that where there was most moisture in the air there was least dust and fewer large particles proportionately to smaller. Tests of relative humidity also showed that in few if any of the rooms was the humidity too high for comfort, though heat was excessive in many cases where testing was done in hot summer weather. In most instances the relative humidity might well have been artificially increased as a means of reducing dust. This could have been done by the use of humidifiers to add moisture to the

air or by supplying cool air in ventilation ducts by means of water sprays or circulation over cold pipes. The mere lowering of the temperature of air increases its relative humidity by lowering its saturation point.

X-ray examinations of the chests of workers in dusty atmosphere showed varying degrees of fibrous deposits in the lungs, as well as fine scattered shadows due to the dust itself. These while well marked in workers in cement and in steel grinders were distinct in potters only after many years of work. Shadows of less degree were also seen in old plush and carpet mill employees, which may have been due in whole or in part to the inorganic matter mixed with the fibrous dust in an old mill not kept any too clean. Evidence of damage to the lungs of cigar workers was absent even in the men working many years at the trade.

Dust conditions in many factories or in parts of factories were minimized by the introduction of strong local exhaust ventilation with hoods over dust-creating machinery, but these were by no means universal and where employed were not always properly constructed or of sufficient size and power, and at times were not even working. Where sufficient suction ducts were in operation the effects of exhaust ventilation on the various-sized particles could be tested and as would be expected it was clearly shown that in addition to lessening total dust it removed a portion of smaller, more dangerous particles.

In general, dust may be prevented or lessened by removal at the source as indicated above, by substitutions of wet for dry processes, by frequent vacuum cleaning or wet sweeping and by increasing relative humidity. In numerous cases dust-generating processes can be entirely enclosed in specially ventilated drums, boxes or rooms, so as to allow no dust to escape into the factory. Where dust can not be prevented dusty processes should be conducted in separate rooms and, especially if the dust is poisonous or very irritating, workers may wear masks or dust helmets. Almost always there can be found some way to protect the workers from excessive dust and such means will be more generally employed when such investigations as these prove more definitely the harmfulness or relative harmlessness of specific dusts and processes.